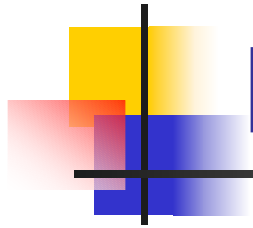


Hydrogen Safety

U.S.

Department of Energy

January 2003



Hydrogen Fundamentals

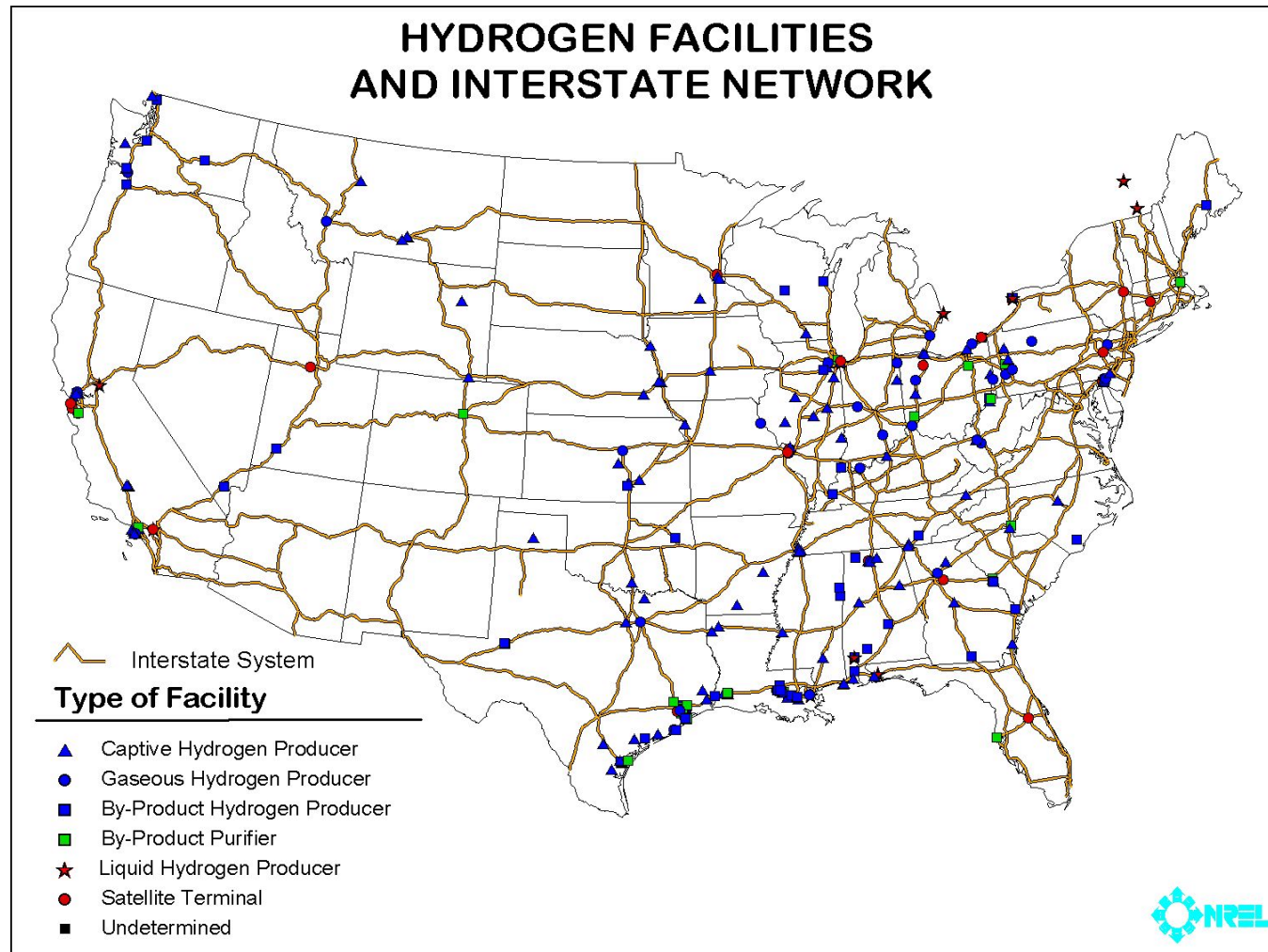
- Energy Content: 60,958 Btu/lb – highest energy content of all fuels on a **weight** basis
 - This is why NASA uses hydrogen – they care a lot more about weight than volume)
 - Energy content is about three times higher than gasoline, natural gas, and propane on a **weight** basis
 - Energy content is only about one third that of natural gas and about an eighth that of propane on a **volume** basis
- Flammability limits (in air): 4.1 v% - 74 v%
- Explosion limits (in air): 18.3 v% - 59 v%



Hydrogen Today

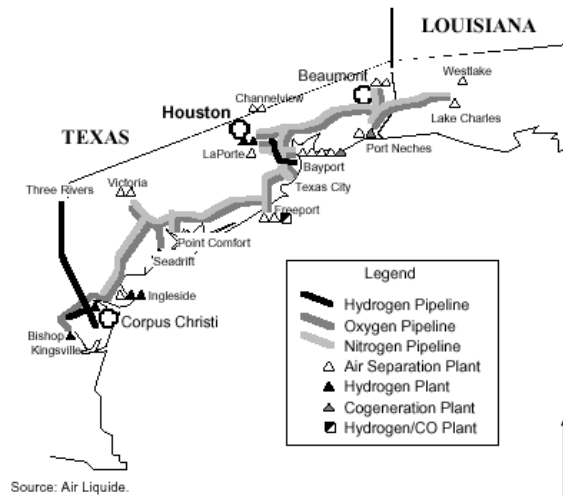
- Production (9 million tons per year)
 - Steam methane reforming
 - Electrolysis
 - Byproduct
- Uses – largely in industrial settings
 - Petroleum upgrading
 - Food processing (hydrogenation)
 - Semiconductor processing
 - NASA (only large-scale fuel use)
- Transporting/Delivery
 - Pipeline
 - Liquid tanker
 - Tube trailer (compressed gas)

Hydrogen Facilities in the US

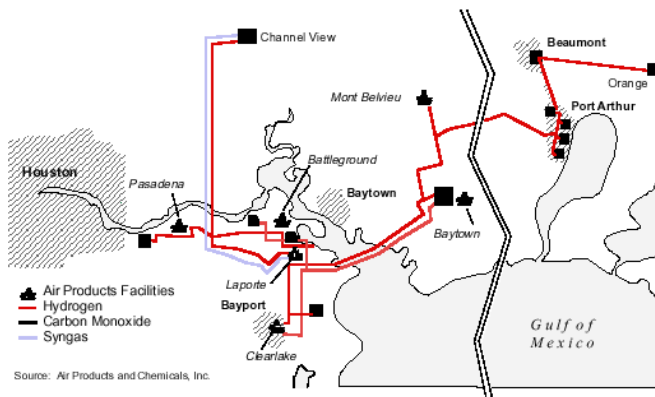


Hydrogen Pipelines

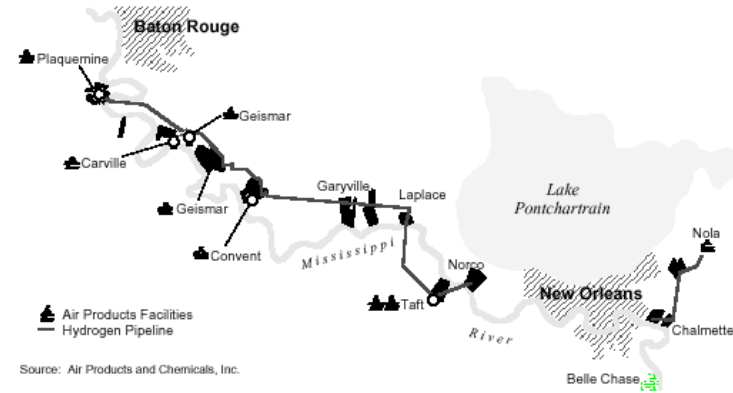
Air Liquide Gulf Coast Pipeline System



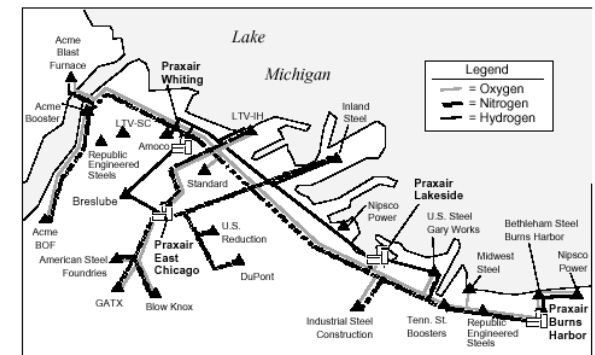
Air Products' U.S. Texas Gulf Coast Hydrogen Pipeline System



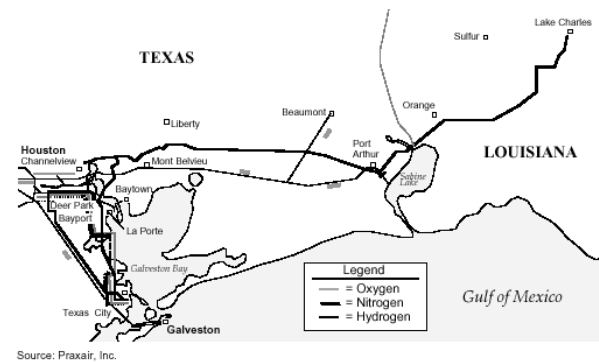
Air Products' Louisiana Hydrogen Pipeline System

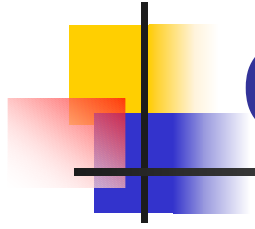


Praxair's Chicago Area Pipeline System



Praxair's U.S. Gulf Coast Hydrogen Pipeline System





Codes and Standards

- Code-making bodies in the US
 - About 20 major developers (excluding federal agencies such as EPA and DOT)
 - Nearly all is done using a consensus process
- Must be adopted by each jurisdiction to be “legal” and binding
 - Approximately 44,000 jurisdictions in the US
 - Federal, state, county, city or town



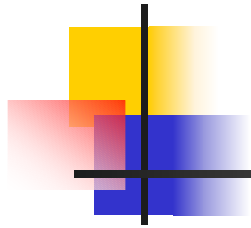
Code Developers

- International Code Council, Inc. (ICC)
 - Building Officials and Code Administrators International (BOCA)
 - International Conference of Building Officials (ICBO)
 - Southern Building Code Congress International, Inc. (SBCC)
- Underwriters Laboratories (UL)
- National Fire Protection Association (NFPA)
- CSA International
- Society of Automotive Engineers (SAE)
- Institute of Electrical and Electronic Engineers (IEEE)
- American Society of Mechanical Engineers (ASME)
- International Electrotechnical Commission (IEC)
- International Organization for Standards (ISO)
- Compressed Gas Association (CGA)
- Natural Gas Institute (NGI)
- US Department of Transportation
- Occupational Health and Safety Administration (OHSA)



Issues

- Codes & standards are being developed in advance of, or in parallel with, hydrogen-fueled systems
 - Codes & standards development must be coordinated with technology development
 - Efforts should be devoted to R&D efforts to validate proposed standards (i.e., need data to support or validate proposed requirements)
- Coordination is vital
 - All applications involve production, transportation, storage, dispensing, and use of hydrogen
 - A large number of organizations are involved in generating codes & standards



Key Codes

Component Technology	Codes	Status
Production	NFPA 70/ NEC/CEC ASME Boiler-Pressure Vessel Sec. VIII	mature mature
Transportation:	DOT 49 CFR	mature mature
Pipeline	NEC/CEC ANSI/ASME B31.1, B31.8	mature mature
Storage	NFPA 50 A: Gaseous Hydrogen NFPA 50 B: Liquid Hydrogen ASME Boiler-Pressure Vessel Sec. VIII	mature (1994) mature (1994) mature
Vehicle Refueling Stations	HV-3: Hydrogen Vehicle Fuel NFPA 52: CNG Vehicle Fuel HV-1: Hydrogen Vehicle Connector NGV1: NGV connectors	being developed base for HV-3 being developed base for HV-1
Hydrogen Vehicles	HV-3: Hydrogen Vehicle Fuel NFPA 52: CNG Vehicle Fuel HV-2: Gaseous Hydrogen Tanks NGV2: CNG Storage Tanks	being developed base for HV-3 being developed base for HV-2



ISO-TC197

Identification Number	Title	Working Group	Convener (Country)
DIS 13984	Liquid H ₂ - Land Vehicle Fueling System Interface	WG 1	SCC (Canada)
DIS 14687	H ₂ Fuel-Product Specification	WG 3	ANSI (USA)
NP 15594	Airport H ₂ Fueling Facility	WG 4	DIN (Germany)
NP 15866	Gaseous H ₂ and H ₂ Blends-- Vehicular Fuel Systems	WG 5	ANSI (USA)
NP 15869	Gaseous H ₂ - Vehicle fuel tanks	WG 6	ANSI (USA)
NP 15916	Basic requirements for safety of H ₂ systems	WG 7	DIN (Germany)
WD 13985	Liquid H ₂ - Land vehicle fuel tank		SCC (Canada)
WD 13986	Tank containers for multimodal transport of liquid H ₂		SCC (Canada)

Hydrogen Uses - Tomorrow

- Mobile Applications

- Fuel cell vehicles (buses, trucks, passenger)
- Modified ICEs



- Stationary Applications

- Uninterruptible power supplies
- Backup/premium power
- CHP

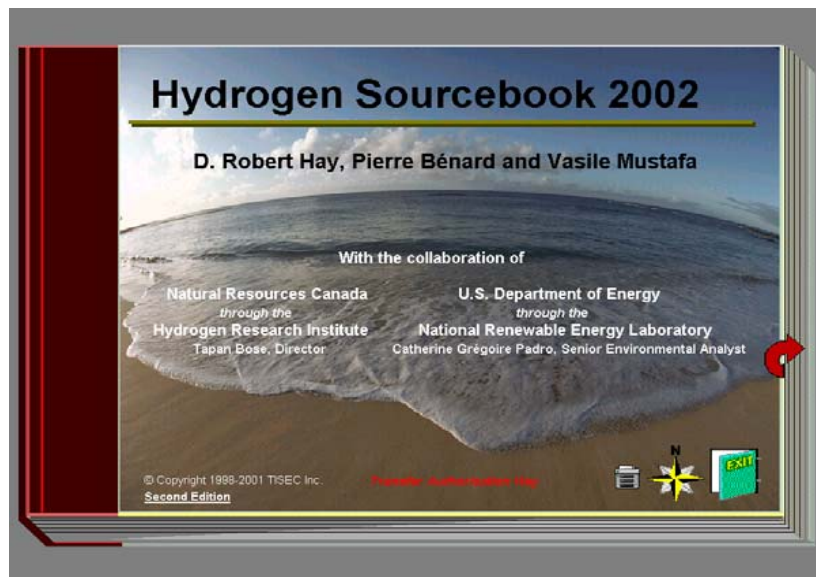


- Portable Applications



Guidelines for Hydrogen Systems

- The Hydrogen Handbook for Building Code and Fire Safety Officials
- The Hydrogen Sourcebook



*THE HYDROGEN HANDBOOK FOR BUILDING CODE
AND FIRE SAFETY OFFICIALS
(Current and Emerging Uses Of Hydrogen as an Energy Resource
and Properties of Hydrogen Compared to Other Fuels)*

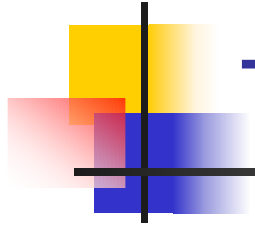


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Energy Efficiency and Renewable Energy
Office of Power Technologies
1000 Independence Avenue, SW
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National Renewable Energy Laboratory
Hydrogen Program
1617 Cole Boulevard
Golden, CO 80401

National Hydrogen Association
1800 M Street, NW Suite 300
Washington, DC 20036





Typical Hydrogen Site Plan Review

- Confinement
- Review Potential for Ignition
- Minimizing Consequences
- Review the Need for Detectors
- Safety Analysis
- Review Site-Specific Factors
- Personal Investigation

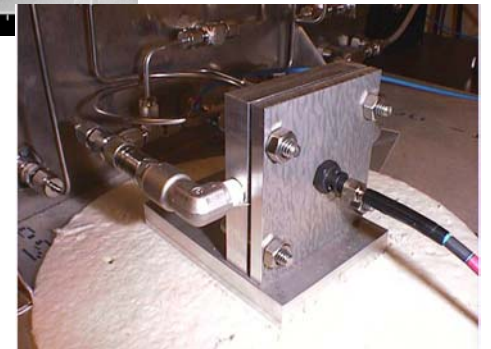
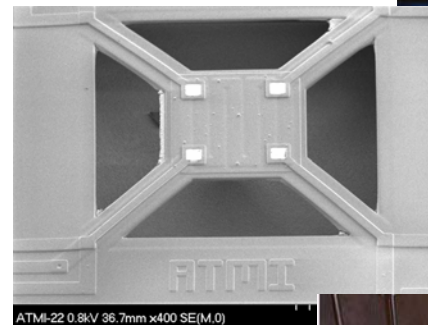
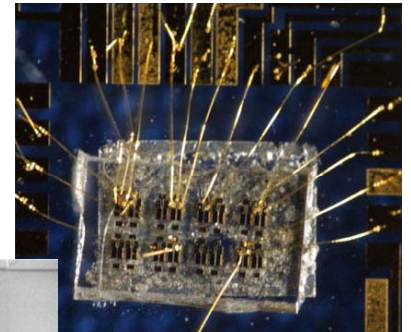
Detection

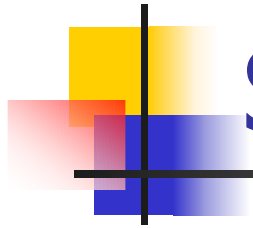
- Sensors

- Safe, reliable, cheap sensors being developed
- Placement is important

- Odorants

- Diffusion/dispersion matching is difficult
- Poison to fuel cell?





Safe Hydrogen Systems

- Safety issues can be handled through testing, certification, and codes & standards, just like with any other fuel
- Sustained, collaborative government-industry RD&D needed
 - Fuel cell and vehicle systems development are critical
 - Infrastructure and codes & standards development require significant government participation (on all levels)
 - Coordination is key



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